# STUDY OF THE "OPERATIVE REST" STATE IN MAN

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16. Abstract

A four-hour laboratory test has been conducted to study the physiological aspects of simple expectation of the presentation of emergency light and sound signals and such expectation accompanied by additional electric stimulation of the muscular nerves of the lower extremities. The results of the experiment are presented and discussed in the context of automation of labor.

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# STUDY OF THE "OPERATIVE REST" STATE IN MAN

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As we know, the term "operative rest" was introduced into the physiology /99* of animal and human behavior by A. A. Ukhtomskiy. This term is understood to mean an evolutionary achievement consisting in the ability of an organism to check action until the moment required, when quick reaction is called for. Such constant readiness for immediate action is the more costly to the organism the longer is the period over which it must be maintained.

In the opinion of M. I. Vinogradov (1966), operative rest is a form of dominant adjustment in which the thresholds of excitability to various environmental stimuli are raised, but the system possesses a high lability permitting transition to immediate discharge. In the biological world a form of activity such as this affords a number of advantages in the struggle for existence and survival of the fittest. The question of activity of this kind is becoming more and more timely in human society, in which labor predominates. The point is that the main line of progress in the labor process consists in transfer to the tools of labor (equipment) of an increasing number of functions previously performed directly by man and his organs. This is the line of labor automation. In the case of advanced forms of automation man is called upon to intervene in the labor process only in emergency situations. Such instances are generally rare, but each of them is highly important, for which reason they require a high level of operative rest, an intent anticipation of a possible emergency signal.

Automation involves transition from contact forms of labor to distant ones, to control of the labor process at a distance, by means of control desks. These forms of labor are becoming more and more common and in the future it is

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*Numbers in the margin indicate pagination in the foreign text.

they which will be used exclusively. The human operator is in this case obliged to observe with close attention the signals coming from the desk. The more reliable the system, however, the rarer is there a signal, and the operator is consigned to apparent "inaction." This is unnatural for a living system. We encounter here a contradiction: in creating advanced equipment man places himself in non-optimum conditions in operating it. Two factors having a negative effect in protracted maintenance of a state of readiness for immediate action are rendered prominent: a shortage of external stimuli, a "sensory hunger" and a lack of muscular activity, hypodynamia. The consequences of these factors for the organism are well known. They lead to lowering of the tonus and of the general level of activity of the organism and to inhibitory effects in the regulatory apparatus. What measures can be taken to /100
counteract them? We believe that one of the effective measures could be, on the one hand, creation of additional activity for the operator which activates the sensory field but does not disrupt the dominant of attention on the main emergency signal, and on the other hand, intensification of the dynamic component for the muscular system. This would make it possible to establish conditions under which the distractions inevitable in inaction which disrupt the dominant of attention on the main stimulus would be eliminated, and would also greatly facilitate transition from reduced tonus or, very probably, from a state of somnolent inhibition to a working level to eliminate malfunctions in the technical system. We have organized a laboratory experiment to prove the thesis advanced in the foregoing.

The state of simple anticipation of an emergency signal given on the average every 40 minutes was studied in 12 subjects under the model conditions of a four-hour experiment involving the use of a control desk emitting light and sound signals (34 light indicators, cathode-ray oscillograph screen, loudspeakers connected to sound generators, and 50 buttons and toggle switches). This state of the subject was compared under the same specific adjustments with other states in which a system of additional signals was introduced and electric stimulation of certain muscular nerves of the lower extremities was applied. The comparison was based on the effectiveness of achievement of the goal, the value of the reaction time to an emergency signal and the indicator of the functional state of the worker. The values of the critical flash frequency (CFF), the characteristics of the myotonic activity based on the EMG recorded at the gastrocnemius and anterior tibial muscles, and the cardiac rhythm were selected as these indicators. (The electroencephalogram, the data of which have not been incorporated in the present paper, were also recorded.)

The system of additional signals was constructed in accordance with the following criteria. In content the signals and the responses to them varied in complexity, from a simple sensomotor reaction to several consecutive reactions connected by logical structure. The frequencies of occurrence of the signals of varying degrees of complexity were distributed in accordance with the exponential law, the complex signals occurring much more infrequently than simple ones. The signals were presented in random order in time. Three densities of signals presented (ranging from lower to higher), 0.0125, 0.025, and 0.05 signals/second, were tested.

Electric stimulation was applied as a method of proprioceptive stimulation of the regulatory apparatus (cortical and subcortical), without distracting the attention of the worker from performance of his basic function. Stimulating cutaneous electrodes were applied to both extremities in the popliteal fossa. Chiefly the tibial nerve was subjected to stimulation. The stimulation was effected with an KES-ZM combined electronic stimualtor. The pulse frequency ranged from 40 to 80/second, the duration of the individual pulse being 0.1-1.0 millisec. The intensity of the stimulus was determined individually each time, on the basis of the value of the motor response to single stimulation, and exceeded the stimulation threshold of the motor axons by 30%. The time and duration of the electric stimulation session were adapted to previous electromyogram recordings characterizing spontaneous myotonic outbursts.

Let us now take up the results of the experiment. Comparative data on the time of reaction to an emergency signal under various conditions of presentation of additional signals are given in Table 1. It is to be seen /101
from the table that the minimum mean arithmatic time of reaction to an emergency signal M, as well as the minimum root mean square deviation σ, was observed at the highest selected density of flow of additional signals (180 signals/hour or 0.05 signals/sec). This time decreased by 30% in comparison to

simple expectation, and became more stable. The dynamics of the time of reaction to an emergency signal in the course of the four-hour experiment is illustrated in Figure 1.

TABLE 1. TIME OF REACTION TO EMERGENCY SIGNAL IN SIMPLE EXPECTATION AND WITH FLOW OF ADDITIONAL SIGNALS, SEC.

| Simple Expectation of Emergency Signal | | Expectation of Emergency Signal With Average Density per Second of Additional Signals of | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0.05 Sig./sec | | 0.025 Sig./sec | | 0.0125 Sig./sec | |
| M | σ | M | σ | M | σ | M | σ |
| 36.4 | 7.6 | 25.5 | 3.4 | 28.6 | 4.8 | 32.2 | 4.5 |

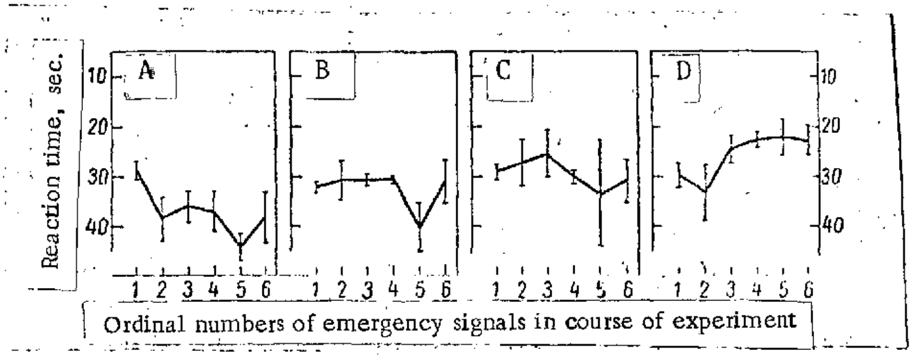


Figure 1. Time of Performance of Emergency Operation in the Course of Operators' Work With Varying Density of Flow of Additional Signals (With an average interval between consecutive operations of around 40 minutes).

A, Simple expectation of emergency signal; B, Expectation including presentation of additional signals of a density of 0.0125 signal/sec; C, Same with density of flow of 0.025 signal/sec; D, Same with density of flow of 0.05 signal/sec. The vertical lines designate the mean value error.

It is to be seen from the illustration that a pronounced decrement in the work of the operator is observed in simple expectation. In addition, a considerable dispersion of the reaction time values on each presentation of the emergency signal is also to be noted under these conditions. With a signal flow density of 0.0125 signal/sec the level of the reaction time values is more stable, with the exception of the last presentations of the emergency signal.

A slight decrease in the reaction time is also to be noticed. With a flow density of 0.025 signal/sec a certain acceleration of the performance of emergency situations is observed even at the beginning of work, but there is also an increase in the dispersion of the values. A flow density of 0.05 signal/sec favors general acceleration of the performance of energy operations, and the work proceeds without a decrement.

It must be noted that there were virtually no errors in the work of the operators in our experiment; this may be attributed to the preliminary training conducted in the course of several experiments.

The effect of electric stimulation on the reaction time is to be seen from the data given in Table 2. /102

TABLE 2. TIME OF REACTION TO EMERGENCY SIGNAL WITH ADDITIONAL SIGNALS OF VARYING DENSITY AND WITH ELECTRIC STIMULATION APPLIED, SEC.

| 0.05 signal/sec | | 0.05 sig./sec + Elec. stimulation | | 0.025 signal/sec | | 0.025 sig./sec + Elec. stimulation | | 0.0125 signal/sec | | 0.0125 sig./sec + Electric Stimulation | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| M | σ | M | σ | M | σ | M | σ | M | σ | M | σ |
| 25.2 | 3.5 | 22.0 | 3.3 | 30.5 | 7.9 | 25.6 | 5.8 | 32.1 | 6.1 | 24.4 | 2.9 |

There is observed in all cases an appreciable decrease both in the mean arithmetic value of the reaction time M and in the root mean square deviation σ from M on addition of the electric stimulation.

Let us consider the indicators characterizing the functional state of the operator. The CFF indicator may be regarded not only as an indicator of the lability of the visual analyzer centers but also as an indicator reflecting the functional state of the central nervous system as a whole. The variation in this indicator under the influence of introduction of a flow of additional signals and electric stimuli are illustrated in Table 3.

It is to be seen from Table 3 that the flow of additional signals with a mean density value of 0.05 signal/sec increases the mean CFF value somewhat during the experiment, and also reduces the scattering of these values. The results of the influence are manifested to a greater degree on addition of the electric stimulation than without it.

TABLE 3. AVERAGE CFF VALUES AND POSSIBLE ERRORS IN THESE VALUES IN OPERATOR A. S. DURING WORK UNDER CONDITIONS OF SIMPLE EXPECTATION OF EMERGENCY SIGNALS AND ON ADMINISTRATION OF ADDITIONAL SIGNALS ACCOMPANIED BY APPLICATION OF ELECTRIC STIMULATION

| Operator Working Conditions | Mean CFF Values at 0.5 Hour Work Intervals | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | $M_1$ | $M_2$ | $M_3$ | $M_4$ | $M_5$ | $M_6$ | $M_7$ | $M_8$ |
| Simple expectation of Emergency Signal | 41.66 ± 0.15 | 40.9 ± 0.2 | 41.3 ± 0.2 | 40.15 ± 0.20 | 40.50 ± 0.18 | 40.00 ± 0.18 | 40.7 ± 0.2 | 39.9 ± 0.2 |
| Expectation accompanied by presentation of additional signals of a density of 0.05 signals/sec and by application of electric stimulation. | 42.80 ± 0.16 | 42.4 ± 0.2 | 42.56 ±0.20 | 42.86 ± 0.20 | 42.34 ± 0.14 | 42.38 ± 0.20 | 42.5 ± 0.2 | 42.53 ± 0.12 |

Analysis of the dynamics of the CFF in the course of the experiment reveals that this indicator decreases to a greater extent with simple signal expectation than in the case of additional activation. This is especially noticeable in analysis of the normalized displacements of the CFF values given in Table 4.

Hence sensory and proprioceptive stimulation improve the functional state of an operator in a situation of operative rest.

The variations in myotonic activity are shown in Figure 2. The indicator of this activity is /103

$$I = \frac{\Delta t \cdot \bar{A}}{t_i - t_{i-1}},$$

where $\Delta t$ is the duration of the outbursts of myotonic activity; $\bar{A}$ is the mean amplitude of the biopotentials of the outburst in question; and $t_i$ is the time of cessation of the given outburst.

TABLE 4. NON-NORMALIZED DISPLACEMENTS OF CFF VALUES IN THE COURSE OF WORK IN OPERATOR A. S. AS A FUNCTION OF SIGNAL FLOW DENSITY AND TYPE OF STIMULATION /104

| Operator Working Conditions | Displacements of CFF Values After 2 Hours of Work | Confidence Limits of Difference According to Student | Normalized CFF Displacements after 2 Hours of Work | Displacements of CFF Values After 4 Hours of Work | Confidence Limits of Difference According to Student | Normalized Displacements of CFF After 4 Hours of Work |
|---|---|---|---|---|---|---|
| Simple expectation | 1.16 | ± 0.12 | 2.85 | 1.76 | ± 0.14 | 4.33 |
| 0.0125 signal/sec | 1.10 | ± 0.12 | 2.70 | 1.30 | ± 0.16 | 3.20 |
| 0.0125 signal/sec + Elec. stimulation | 0.40 | ± 0.05 | 1.02 | 0.80 | ± 0.06 | 2.04 |
| 0.025 signal/sec | 1.10 | ± 0.08 | 2.60 | 1.10 | ± 0.10 | 2.60 |
| 0.025 signal/sec + Elec. stimulation | 0.36 | ± 0.09 | 0.86 | 0.70 | ± 0.09 | 1.70 |
| 0.05 signal/sec | 0.40 | ± 0.08 | 0.95 | 0.58 | ± 0.12 | 1.40 |
| 0.05 signal/sec + Elec. stimulation | 0.46 | ± 0.10 | 1.08 | 0.27 | ± 0.09 | 0.63 |

It is to be seen from Figure 2 that with simple expectation of emergency signals the sensory deprivation (insufficiency) is compensated by increased myotonic activity, which has a random and approximately even distribution in time, with a certain increase in the activity in the course of work. With a signal flow density of 0.0125 signal/sec and 0.025 signal/sec the activity as a whole is less pronounced: it is concentrated chiefly in the middle of the work period. With the maximum signal flow density the myotonic outbursts occur only after two hours of work, but are more pronounced. It may be mentioned in passing that this fact coincides with the subjective sensation of a certain amount of difficulty observed in the operators during the third hour of work.

The distribution of the myotonic activity in time permits full evaluation of the specific nature of the effects of the additional signals and determination of the moments in time when additional proprioceptive stimulation is necessary.

Lastly, the variation in the cardiac rhythm is shown in Figure 3. It is to be seen that the dispersion value in performance of an emergency operation decreases in all cases. As regards the value of the additional activity by the operator, it obviously derives from the data obtained: the cardiac rhythm becomes more stable.

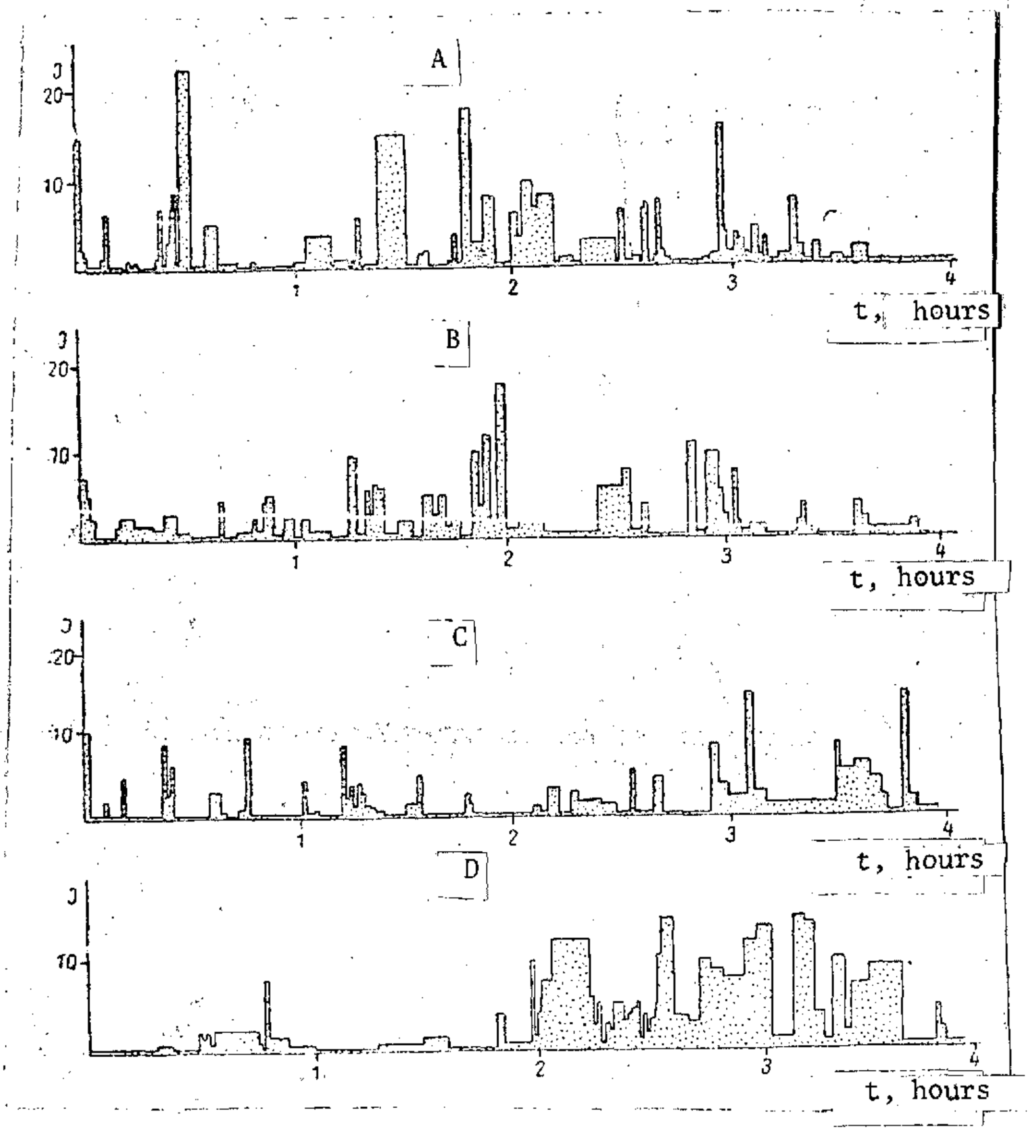


Figure 2. Distribution of Outbursts of Myotonic Activity in the Course of Work in Operator Yu. R. With Varying Signal Flow Density (Right Anterior Tibial Muscle).

A, Emergency signals only presented; B, Emergency signals plus additional signals of a density of 0.0125 signal/sec; C, Same with density of 0.025 signal/sec; D, Same with density of 0.05 signal/sec.

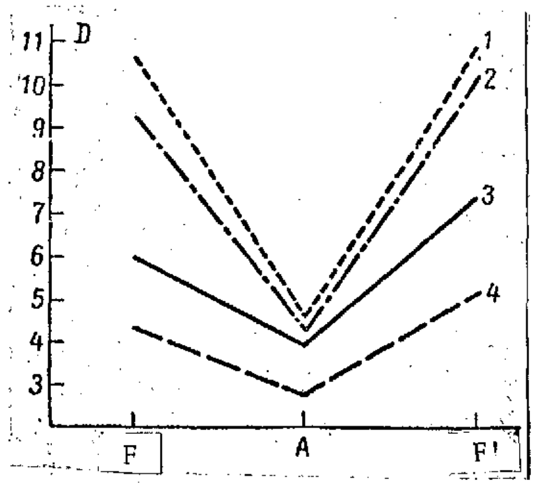


Figure 3. Modification of Variability of Cardiac Rhythm in Response to an Emergency Situation.

1, Simple expectation of emergency signals; 2, Additional signals of density of 0.0125 signal/sec; 3, Same, of density of 0.025 signal/sec; 4, Same, of density of 0.05 signal/sec. Y-axis, Dispersion of ECG P-P intervals in conventional units (D). F, D value to time of arrival of emergency signal; A, D value during performance of emergency operations; F', D value after emergency.

In recapitulation of the data obtained it may be stated that additional activation of operator activity yielded positive results. There is obviously a need for further research to ascertain the physiological mechanisms of operative rest, as well as for the taking of measures for the creation of optimum conditions of human work with the new labor technique. These are measures contributing to maintenance of the working tonus at a high level. It is /105 important to note that the attention of foreign specialists in experimental psychology is concentrated on the state of readiness for action associated with the new labor conditions. It suffices to refer to the work of Baker (1959), Deese (1955), Jenkins (1958), Hebb (1955), and others. In the opinion of M. I. Vinogradov (1967), operative rest represents the physiological foundation of any form of operator labor.

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